

Complete Ionisation of the Neutral Gas in High Redshift Radio Galaxies and Quasars

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Abstract. Cool neutral gas provides the raw material for all star formation in the Universe, and yet, from a survey of the hosts of high redshift radio galaxies and quasars, we find a complete dearth of atomic (H I 21-cm) and molecular (OH, CO, HCO⁺ & HCN) absorption at redshifts $z \gtrsim 3$ (Curran et al. 2008). Upon a thorough analysis of the optical photometry, we find that all of our targets have ionising ($\lambda \leq 912 \text{ \AA}$) ultra-violet continuum luminosities of $L_{UV} \gtrsim 10^{23} \text{ W Hz}^{-1}$. We therefore attribute this deficit to the traditional optical selection of targets biasing surveys towards the most ultra-violet luminous objects, where the intense radiation excites the neutral gas to the point where it cannot engage in star formation (Curran & Whiting 2010). However, this hypothesis does not explain why there is a critical luminosity, rather than a continuum where the detections gradually become fewer and fewer as the harshness of the radiation increases. We show that by placing a quasar within a galaxy of gas there is *always* a finite ultra-violet luminosity above which *all* of the gas is ionised. This demonstrates that these galaxies are probably devoid of star-forming material rather than this being at abundances below the sensitivity limits of current radio telescopes.

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For a cloud of hydrogen containing an ionising source, the equilibrium between photoionisation and recombination of protons and electrons in a nebula is given by

$$\int_{\nu_{\text{ion}}}^{\infty} \frac{L_{\nu}}{h\nu} d\nu = 4\pi \int_0^{r_{\text{ion}}} n_p n_e \alpha_A r^2 dr = 4\pi \alpha_A n_0^2 \int_0^{r_{\text{ion}}} e^{-2r/R} r^2 dr,$$

for a gas density $n_p = n_e = n = n_0 e^{-r/R}$, where $n_0 (= 10 \text{ cm}^{-3})$ is the value at $r = 0$ and R is a scale-length describing the rate of decay of this with radius. For the observed critical value of $\int_{\nu_{\text{ion}}}^{\infty} (L_{\nu}/h\nu) d\nu = 3 \times 10^{56} \text{ ionising photons sec}^{-1}$ ($L_{UV} \sim 10^{23} \text{ W Hz}^{-1}$), this gives a scale-length of $R = 3 \text{ kpc}$, which is the value found for the H I in the Milky Way, which has an exponential profile with a similar $n_0 = 13.4 \text{ cm}^{-3}$ (Kalberla & Kerp 2009). That is, the observed critical luminosity is sufficient to ionise all of the gas in a large spiral galaxy, thus explaining why neutral gas is not detected in high redshift optically selected sources (Curran & Whiting 2012). Therefore, even the SKA is unlikely to detect 21-cm absorption within the host galaxies of these objects.

References

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